10/590072
IAP12 Rec'd PCT/PTO 21 AUG 2006

EQUIPMENT FOR THE BIOLOGICAL ACTIVATED SLUDGE TREATMENT OF WASTE-WATER AND PROCEDURE FOR ITS OPERATION

The subject of the invention relates to equipment for the biological activated sludge treatment of waste-water containing organic pollutants, especially municipal or/and food industry waste-water, and a procedure for the operation of such equipment.

There are two basic methods for the biological activated sludge treatment of waste-water containing organic pollutants: continuous and discontinuous (SBR - sequencing batch reactor) technology. The difference between these two solutions is that while in continuous systems the individual cleaning technology operations - removal of organic materials, phosphor and nitrogen, phase separation - are performed in a way that they are separated from each other in space, while in the SBR system these processes take place in the same space, following each other shifted in time. Both systems have their advantages and disadvantages, and this may be the reason for the appearance of solutions based on the combination of the two technologies in the field of waste-water treatment.

The main advantages of the SBR technology are that it can follow hydraulic and pollutant loading fluctuations better than continuous systems, using less energy, and the operational reliability of settling is higher, as in the phase of settling there are no fluid flows influencing the settling of sludge floc. A further advantage of the SBR technology is that even in the case

of low performance demand, e.g. below 100 m_2/day, it can be easily equipped with technological machinery, when for a continuous system of such capacity there are no suitable low capacity waste-water pumps available in commercial distribution any longer, at the same time there is a risk that the pipes with a small cross-section may get blocked.

An important advantage of continuous technologies is that the removal of biological nutrients (N, P) takes place in separate spaces, so the efficiency of these operations is less influenced by operation settings, and their operational reliability is higher. Their further advantage is that - if a pre-denitrification step is inserted in the series of operations, - the nitrate content of the water entering the settling plant is lower, consequently there is a lower chance or risk of sludge levitation deriving from denitrification. In the case of continuous systems the chances are also better for the use of the selector principle to ensure the restriction of filament creation in sludge.

USA patent specification No. 6 406 628 describes a solution for the improvement of the nutrient removal efficiency of the SBR technology. According to this fermented metabolite created in the course of rotting organic wastes is entered into the sequencing batch reactor at the right point in time, as an easily soluble source of carbon. Due to this N and P elimination becomes extremely favourable, but its disadvantage is that additional sludge is created. A further disadvantage is that in respect of the sewage treatment plant of a small settlement the task of collecting, storing and processing organic waste unreasonably increases the labour demand of operation.

The technology described in USA patent specification No. 4 966 705 is based on the combination of continuous and SBR

systems. This system contains a main reactor equipped with a fixed decanter and an anterior reactor performing a balancing and selecting function. It means that the cleaned water of the current previous batch is decanted by displacement by the entered waste-water mass of the current following batch. With the settled sludge taken back to the anterior reactor after decanting the amount of water with a high content of nitrates getting back into the space where denitrification can take place remains below the amount that would make N elimination justified in the course of the treatment of municipal waste-water with average composition. As in this case the amount of the returned liquid determines the minimum amount of the following batch, recirculation cannot be optimised to nutrition elimination.

In the system described in USA patent specifications No. 6 190 554 and 6 398 957 there is also an anterior reactor and a main reactor; in this system recirculation aiming towards the anoxybiotic anterior reactor is dimensioned for nutrition elimination, so the conditions for the denitrification process, that is biological nitrogen elimination, are ensured. A separate anoxybiotic preliminary denitrification space is advantageous, because labile organic materials ensuring rapid denitrification do not dilute in there, but instead they are completely used for nitrate elimination in the lack of solute oxygen. A disadvantage of the system is that it does not ensure sufficient biological phosphorus elimination. Although optionally the system contains an anaerobic reactor, but it is used for sludge digestion, so the phosphorus integrated in the sludge enters the solution again and gets into the main reactor together with the escaped water; it

means that with excess sludge biological phosphorus elimination is not possible.

The task to be solved with the invention is to provide activated sludge biological waste-water treatment equipment and procedure with batch operation, as a result of which it becomes less difficult to provide it with technological machinery even in the case of a low capacity demand or small size, and as a result of the appropriate operation of the equipment it becomes possible to adapt flexibly to hydraulic and pollutant loading fluctuations; on the other hand the solution must ensure with high operational reliability a high efficiency of nitrogen and biological phosphorus elimination, which should be about 90% in the case of nitrogen and 80-85% in the case of phosphorus.

The invention is based on the recognition that if no mixing is performed in the aerated main reactor used for secondary settling, but aeration is performed even during filling, and all operations for which no aeration is needed are performed in an anaerobic/anoxybiotic anterior reactor in which a mechanical mixer is operated in the phase between filling and settling, and from the main reactor water rich in nitrates is taken back to the anterior reactor, then fairly efficient denitrification can be ensured, and organic material and phosphorus elimination can also be solved perfectly.

On the basis of the above recognition, in accordance with the invention the set task was solved with equipment for the treatment of waste-water containing organic pollutants, especially municipal or/and food industry waste-water, which has a main reactor and an anterior reactor and facilities for feeding in untreated sewage, removing cleaned water and sludge and aerating the waste-water entered into the main reactor, and

it also has a mixer situated in the anterior reactor, and which equipment is characterised by that

- between the main reactor and the anterior reactor there is a facility or there are facilities for the recirculation of waste-water.

According to a favourable construction the equipment has a U-shaped pipe piece for recirculation, the one arm of which is situated in the anterior reactor separated from the main reactor with a partition wall, its other arm is situated in the main reactor, and their lower ends are connected with a pipe taken through this partition wall, and their upper ends are situated at a height suiting the minimum water-level determined in these reactors; an air-pipe with an end-fitting ensuring mammoth pump function is connected to the arm of the U-shaped pipe-piece situated in the main reactor; and above the upper end of the arms, at a certain distance there is transfer hole in the partition wall ensuring recirculation; practically the air-pipe branches off the aerating system belonging to the main reactor.

In accordance with another criterion of the invention the aerating system belonging to the main reactor has a blowing device and an air-pipe starting from it, distributor air-pipes that are connected to the above air-pipe and run near the base plate of the main reactor, and air-injection heads connected to these air-pipes.

According to another construction the cleaned-water draining device is a decanting device situated on a floating body. It is also favourable, if there is a pump situated in a compensation basin for feeding in untreated sewage, which pump enters the anterior reactor.

The procedure according to the invention realised by operating the equipment is characterised by that

- in a filling phase the main reactor is filled from a minimum level to a maximum level with untreated sewage first taken into the lower range of the sludge mass situated in the anterior reactor and taken from the anterior reactor to the main reactor, while - in a given case - the water situated in the main reactor is aerated;
- in a following reaction - nitrification - denitrification phase the water situated in the main reactor is aerated, and the water situated in the anterior reactor is mixed, practically mechanically, while the waste-water is recirculated between the two reactors;
- then sludge is settled from the waste-water treated as above; and
- the treated sewage is drained from the equipment by decanting in a way that the water-level in the reactors is reduced to a minimum level; and
- the excess sludge is removed from the reactors.

Below the invention is described in detail on the basis of the attached drawings, which show a favourable construction of the equipment and its operation. In the drawings

figure 1	shows a construction of the equipment in a section taken along line E - E shown in figure 2;
figure 2	is a section taken along line A - A shown in figure 1;

figure 3 is a section taken along line B - B shown in figure 1;

figures 4-7 shows the filling, reaction, settling, cleaned-water draining and excess sludge removing phases of the equipment shown in figures 1-3, in a section taken along line C - C shown in figure 1.

As it can be seen in figures 1-3, the equipment according to the invention has a main reactor I, an anaerobic/anoxybiotic anterior reactor II, a compensation basin III and an excess sludge tank IV, all created inside one single tank structure marked with reference number 10 as a complete unit, and it has a feeding pump 1, a recirculation pump 5 and an excess sludge removing pump 7. The compensation basin III ensures the even loading of the cleaning steps, or in the case of very low loading it ensures the possibility of standstill. The discharge pipe 1a of the feeding pump 1 enters the anterior reactor II, near its base plate 9 (figure 4); in the anterior reactor II there is a mechanical mixer Z below the $\underline{v}_{max}$ water-level (figure 1 and 3). An air-injection device 4 (figure 2) situated outside the tank structure 10 is also a part of the equipment, which is connected to the system of air-distributor pipes 3a running near the base plate 11 of the main reactor I with an air-pipe 4a, and air-injecting heads 3 are connected to the pipes of the distributor pipe system 3a (figures 1-5).

In the case of the present construction the equipment also has a U-shaped pipe piece 15 with its arms stretching upwards, used for recirculating the waste-water between the main reactor

I and the anterior reactor II, and the lower horizontal part of this U-shaped pipe piece 15 is taken through the wall 12, one of its arms 16a stretching upwards provided with a funnel 15a at the top is situated in the anterior reactor II, while its other arm 16b is situated in the main reactor I, and their end openings are situated at the same height. The height at which these openings are situated is determined by defining a minimum water-level height. This pipe-piece 15, as described below, can operate in two modes: on the basis of the law of intercommunicating vessels due to the water-level differences, or as a mammoth pump, because it is connected to the air-injection device 4 shown in figure 2 with an air-pipe 14 containing an end-fitting 13a starting from connection place 14 (also see figure 5), so when the end-fitting 13a is opened - if the air-injection device 4 is in operation - the pipe-piece 15, as a mammoth pump, pumps the water out of the anterior reactor II into the main reactor I. In order to ensure recirculation a transfer opening 8 is created in the upper section of the partition wall 12 separating the main reactor I from the anterior reactor II.

In the main reactor I, in the water-level range following the changing of the water-level there is a decanting device 6a on a floating body 6a moving up and down following the changing of the water-level (figures 1-3), and the offtake pipe 6a is taken outside the tank structure 10.

On the base plate 9 of the anterior reactor II or in its vicinity there is a pump 7 to ensure the removal of excess sludge, and its discharge pipe 7a is taken outside the tank structure 10 or into the excess sludge tank IV.

Below the operation of the equipment according to figures 1-3 - the procedure realised with the equipment - is described in

detail with reference to figures 4-8, where the already described devices are marked with the same reference numbers as used in figures 1-3.

Figure 4 shows the filling phase of the procedure, at the starting of which the $\underline{v}_{min}$ water-level is at the minimum low, decantation level both in the anterior reactor II and in the main reactor I. In the two reactors the filling level is marked with reference letters $\underline{v}_{max}$. During the filling phase the water-levels in the two reactors change together within the range of $\underline{m}$ height. During the filling process the untreated sewage enters the compensation basin III as shown by arrow a, where it can reach a level of $\underline{v}_{1max}$; in the meantime with the feeding pump 1 untreated sewage is fed from the compensation basin III to the bottom of the anterior reactor II as shown by arrow b, preferably without significantly stirring up the sludge settled there in the previous cleaning phase, distributing the untreated sewage in the sludge mass. In the sludge 17 the organic material content of the untreated sewage causes the rapid decreasing of the oxygen level to zero, anaerobic conditions are created, the bacteria cells use up their polyphosphate reserves, and they generate phosphor accumulation in the liquid. In the meantime the water-level rises both in the anterior reactor II and in the main reactor I to the maximum $\underline{v}_{max}$ level - nearly up to the lower rim of the transfer opening 8 -, as through the U-shaped pipe piece 15 practically the main reactor I is filled up at the same time as the anterior reactor II, where the untreated sewage goes as shown by arrow b, but because there is no mixing only a small amount of untreated sewage gets into the main reactor I, where aeration should be practically started through the air-injection heads 3 (also see figures 1-3) during filling by blowing air into the liquid,

which ensures the oxidation of the organic materials stored in the cells and through this the rapid absorption of the organic material content of the batch entered during the actual filling phase.

Depending on the capacity of the current equipment a filling phase can last for 0-60 minutes. Filling is started only when there is a sufficient amount of untreated sewage in the compensation basin III for the batch.

Figure 5 shows the process of the reaction, organic material elimination, nitrification and denitrification, which can generally last for 60-240. At the beginning of this phase the anterior reactor II and the main reactor I are filled up to the maximum water-level. In the anterior reactor II mixing is started by starting up the mechanical mixer 2, and during this phase the sludge combined with untreated sewage is stirred up and mixed with the water containing nitrates that remained from the previous cycle - demixed on top -, and by this the conditions of denitrification are created. In the main reactor I aeration takes place during the complete reaction phase, which results in the elimination of organic materials and the nitrification of ammonia. As these processes are completed, the use of the entered oxygen slows down, which results in a raising level of solute oxygen. When receiving a control signal based on this a control-operation device (not shown here) starts up liquid recirculation between the main reactor I and the anterior reactor II, which process, in the case according to the present construction, with respect to the low lift demand, takes place on the basis of the mammoth pump principle by opening the end fitting 13a (also see figures 1 and 3), as a result of which high-pressure air flows into the arm 16b of the pipe-piece 15 at the

connection point 14 causing the liquid to move. Recirculation takes place through the transfer opening 8 - measuring weir - and the U-shaped pipe-piece 15 as shown by arrows $\underline{c}_1$ - $\underline{c}_3$. As a result of recirculation from the anterior reactor II more activated sludge containing organic materials and ammonia, mixed with untreated sewage gets into the main reactor I, which results in the acceleration of the oxygen absorption processes and the reduction or at least the stabilisation of the solute oxygen level of the reactor. In the meantime activated sludge with a high content of nitrates flows back into the anterior reactor II - practically through a small deoxygenation space (not shown here) - due to gravity. In the anterior reactor II the nitrates are denitrificated with the help of the organic materials that remained there, and by this the elimination of nitrogen from the sewage is ensured.

As recirculation results in the mixing of the water masses situated in the main reactor I and the anterior reactor II, an increasing amount of water is needed to forward one unit of organic pollutants into the main reactor I, so recirculation gradually accelerates. By the end of the reaction phase shown in figure 5 the concentration of pollutants in the two reactors can be more or less the same. All through the complete reaction phase the circumstances prevailing in both reactors make it possible for the bacterium to replace the phosphate lost in the anaerobic phases and accumulate excess phosphate, and by this phosphor elimination by sludge removal, that is biological phosphor elimination is realised.

Generally the settling phase of the procedure shown in figure 6 takes 30-60 minutes. Both air intake in the main reactor I and mixing in the anterior reactor II are suspended during the

whole of the settling process (the necessary machines and devices are not shown in figure 6). By the end of the phase the sludge 17 settles in both reactors to the bottom of the water mass at level $\underline{v}_{max}$. Obviously untreated sewage can arrive in the compensation basin III even during the settling phase, as shown by arrow a.

In the phase of the procedure shown in figure 7 the cleaned water is taken for example to the reception area as shown by arrow e; this phase may take 30-60 minutes, and mixing and aeration is suspended during this phase. In this phase cleaned water of the amount of one batch is taken away, according to the present example with the help of the decanter 6 described above in connection with figures 1-3, which always takes water from the top layer of the water mass of a few centimetres, always the same yield and simultaneously from the main reactor I and from the anterior reactor II, so the sludge 17 at the bottom cannot get mixed in. By the end of the phase the initial maximum $\underline{v}_{max}$ water-level reduces to a minimum $\underline{v}_{min}$ level; This is the lower decantation level, and an amount of one batch is a water mass of $\underline{v}_{max} - \underline{v}_{min} = \underline{m}$ height.

Finally figure 8 shows the excess sludge removal phase of the procedure, which generally takes 5-30 minutes, and for which a pump 7 submerged in the sludge 17 is used as shown in figures 1-3. During this phase the excess biomass created in the system is removed from the system as shown by arrow e. The sludge is discharged into the excess sludge tank IV shown in figure 1. Sludge can be removed from either one of the reactors, because in the course of recirculation the whole water mass is mixed in both reactors so intensively that practically it becomes

a homogenous sludgy mass of water, and during flow there is compensation in this sense too.

Practically the term of the phases stated above do not depend on the nominal capacity of the current equipment, which can be generally 10 - 3000 m^3/day per phase.

It must be pointed out that air-injection aeration method described above other ordinary - e.g. mechanical oxygen intake, etc. - aeration methods can also be used.

Consequently on the basis of the above the cleaning process takes place according to the classical cycles - phases - such as filling - reaction - settling - cleaned water decantation - excess sludge removal. As compared to the traditional SBR system the basic difference is that on the one part there is no mixer in the main reactor I, aeration takes place in there practically during the filling phase, and it is suspended only during the settling, decantation and excess sludge removal phases, as the processes for which no aeration is required take place in the anterior reactor II, where the mechanical mixer operates in the phase between filling and settling and it does not operate during the filling phase. At this point untreated sewage is entered into the sludge 17 settled in the anterior reactor II, practically in batches, at a low rate to avoid the sludge getting stirred up. During filling anaerobic conditions are created in the sludge layer, as a result of which the conditions of biological phosphor elimination are created. During the filling phase the filling of the main reactor I is also started through the overflow pipe - pipe-piece 15 - situated at the decantation level, and although no significant amount of untreated water gets here during the filling phase, aeration can be started, as a result of which the organic materials absorbed by the biomass are

decomposed, and the absorption of organic materials is faster when the untreated sewage is mixed in.

In the reaction phase, maybe at the end of the filling phase, by operating the mechanic mixer in the anaerobic/anoxybiotic anterior reactor II the water with a high content of nitrates that remained there from the previous cycle in the top layer is mixed with the untreated sewage and the activated sludge in the lower layers, which, due to the presence of the soluble organic materials, results in rapid denitrification. As it has been described above, in the reaction phase (figure 5) the sewage containing activated sludge is pumped from the anterior reactor II into the main reactor I with a mammoth pump, and a discharge mouth - the transfer opening 8 - ensures recirculation towards the anterior reactor II. The flow towards the main reactor I takes organic materials and ammonia here, which create a demand for oxygen, and the water flowing through the discharge mouth takes nitrates into the anterior reactor II. The rate of recirculation gradually accelerates as programmed in advance. The decomposition of the organic materials and the nitrification of the ammonia results in the decreasing of the oxygen demand in the aerated space, so in order to make use of the aeration capacity a further amount of untreated sewage mixed with more activated sludge needs to be entered into the main reactor using its decomposing activity. Due to the recirculation dilution the organic pollutant concentration of the anoxybiotic anterior reactor gradually decreases, so increasingly faster recirculation is needed for using up the oxygen intake. By the end of the aeration cycle a completely mixed system is created.

In summary it can be stated that

- in the anterior reactor anaerobic, anoxybiotic and sedimentation processes take place, while in the main reactor aerobic and sedimentation processes take place, the reduction of the biologically decomposable organic material content of the waste-water by accumulation and the increasing of the phosphorus content caused by it takes place in the anterior reactor, while the nearly complete elimination of the organic material and phosphorus content takes place in the main reactor;
- the transformation of the nitrogen content of the biologically decomposable pollutants by nitrification takes place in the main reactor, while the biological elimination of the nitrates created in the course of the nitrification (denitrification) takes place in the anterior reactor.

Finally we are emphasising the possibility that vegetation can be planted in both the main reactor I and the anterior reactor II in a way that in the case of a reactor with a fixed water-level vegetation is planted on a grid fitted near the water surface, while in the case of a reactor with a changing water-level vegetation is planted on a grid fitted on a floating body. In both cases the roots grow into the water of the reactor space. The plant roots with a great specific surface, due to the micro organisms settling on them, realise submerged fixed-film biological cleaning supplementing the activated sludge system, that is they facilitate biochemical reactions on the roots and intensify the cleaning technology.

The advantage of the invention is that the aeration capacity does not need to be dimensioned on the basis of the traditionally large oxygen demand after feeding in the case of the ordinary SBR systems, and by keeping the oxygen

consumption at a more or less permanent level the aeration volume is used to the maximum. Furthermore there is no need to invest in a frequency converter regulating the air injector.

Obviously the invention is not restricted to the concrete construction of the equipment or the realisation of the procedure described above, but it can be realised in several different ways within the scope of protection determined by the claims.